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ABSTRACT

The Educational Leaders in Mathematics (ELM) Project, was an experimental inservice program for teachers of mathematics, grades kindergarten to 12. The major focus on the project was to help teachers develop and implement approaches to mathematics instruction based on a constructivist view of learning. ELM demonstrated the significant impact of combining constructivist summer inservice institutes with intensive, ongoing follow-up support. Teachers not only integrated into their instruction new strategies, but also showed evidence of having developed constructivist views of mathematics learning as a basis for their instructional decisions. Students attitude scores and teachers observations reflected improvements in students' attitudes about, conceptions of, and communication in mathematics as well as in problem solving and conceptual understanding. ELM demonstrated that teachers can make student understanding and problem solving high priority and decrease emphasis on computational skills without a drop of in tests results. This monograph describes the ELM Project's philosophical basis and methodology, and presents the instrumentation results, and conclusions in detail. A bibliography is included, and questionnaires and student attitude surveys are appended. (Author/JD)

TEACHER EDUCATION FROM A CONSTRUCTIVIST PERSPECTIVE:

The Educational Leaders in Mathematics Project

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TEACHER EDUCATION FROM A CONSTRUCTIVIST PERSPECTIVE: THE EDUCATIONAL LEADERS IN MATHEMATICS PROJECT

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Abstract

The Educational Leaders in Mathematics (ELM) Project, was an experimental inservice program for teachers of mathematics, grades kindergarten to twelve. The major focus of the Project was to help teachers develop and implement approaches to mathematics instruction based on a constructivist view of learning.

ELM demonstrated the significant impact of combining constructivist, summer, inservice institutes with intensive, ongoing follow-up support. Teachers not only integrated into their instruction new strategies, but also showed evidence of having developed constructivist views of mathematics learning as a basis for their instructional decisions.

Students attitude scores and teachers observations reflected improvements in students' attitudes about, conceptions of, and communication in mathematics as well as in problem solving and conceptual understanding. ELM demonstrated that teachers can make student understanding and problem solving high priority and decrease emphasis on computational skills without a drop off in tests results.

This monograph describes the ELM Project's philosophical basis and methodology, and presents the instrumentation results, and conclusions in detail.

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CHAPTER 1

INTRODUCTION

The Educational Leaders in Mathematics (ELM) Project which was conducted by the SummerMath for Teachers Program at Mount Holyoke College was an experimental inservice program for teachers of mathematics, grades kindergarten to twelve. The major focus of the project was to help teachers develop and implement approaches to mathematics instruction based on a constructivist view of learning. To this end, the project combined summer institutes with intensive classroom supervision at the initial level, and included an inservice leader apprenticeship program at the advanced level. A wide variety of assessment tools were used to study the effects of the Project.

This monograph describes the ELM Project's philosophical basis and methodology, and presents the results and conclusions from this work. The limits of the program are explored and the design of "next steps" informed by ELM Project work are delineated.

Pedagogical Principles

In recent years pre-college mathematics instruction has become a problem of national concern. American business and government have made quality mathematics and science education a priority because they perceive that the lack of quality education is eroding the United States' position as a leader in science and technology. In particular, they are demanding that the schools prepare students who can solve problems and think critically and creatively (Goldberg and Harvey, 1983).

Mathematics education therefore must be changed to meet new conditions in the modern world (National Science Foundation, 1983). The increased use of computers and the proliferation of new information call for students who can think mathematically rather than merely memorize formulae and manipulate mathematical symbols (Fey, 1984). Conceptual understanding, skill in solving problems, and the ability to learn new mathematics will serve Americans far better in the 1990's and beyond (National Council of Teachers of Mathematics, 1980; Papert, 1980; Schoenfeld, 1983; NAEP, 1983, National Research Council, 1989).

Conventional approaches to mathematics instruction generally have failed to foster the skills and understanding that have been called for. Teachers of mathematics who tend to follow the textbooks in a lock step fashion spend a majority of their time lecturing to students, providing them with information to be memorized, and modeling sample problems to be used as templates for the solution of nearly identical problems. Students who have been taught in this way often learn to be successful mathematics students by memorizing algorithms or procedures for solving problems. Many of these successful students, when attempting to study more advanced mathematics, find that their method of learning mathematics is inadequate. They have not developed skills in thinking mathematically. More advanced mathematics, therefore, is off-limits to them as are many mathematics-related career choices.

Constructivism is a view of learning that may provide a foundation for mathematics instruction which addresses these educational shortcomings. According to the constructivist perspective, meaning and understanding are constructed by the learner (von Glasersfeld, 1983). Only through active cognitive involvement do conceptual understanding and problem solving skills develop. Active cognitive involvement refers to making connections to past learning, constructing new representations and models of reality, and struggling with the conflict between existing personal models of the world and discrepant new information. Piaget (Wadsworth, 1984) empirically demonstrated the interactive nature of learning; learner's must actively operate on new information while bringing to bear prior experience and cognitive structures.

Constructivism runs counter to the notion that a teacher can pass on her understanding to passive learners, who incorporate exact copies of the teacher's understanding for their own use. In contrast, a constructivist view of learning suggests an approach to teaching that gives students the opportunity for concrete experience through which they can discover patterns and build concepts as a solid foundation for more abstract understanding. The mathematics classroom is viewed as a problem solving environment (NCTM, 1987) in which developing generalized problem solving skills, expanding creative thinking, and building confidence to approach new problems are valued more than the answers to particular problems or the rote memorization of algorithms.

Instruction of this type, while applicable to diverse populations of students, has been identified as being responsive to the particular learning needs of women (Belenky et al. 1986).

The role of the teacher in such a classroom is different from that in the traditional classroom. The teacher is no longer the teller, but the creator of problem solving situations which focus students on the discovery of new ideas and new understandings. The teacher attempts to select tasks which require a cognitive reorganization in order to be solved. The student is challenged to use his previous knowledge in new ways and to extend or alter his previous understandings. In order to accomplish this, the tasks must be grounded in experiences that are familiar or accessible to the students. Thus, the mathematical concept to be learned must be embedded in the context of real world situations that are within the students' common experience, in physical objects that they can manipulate, or mathematical structures that are already solidly known. Using this firm base, students solve novel problems, discover new relationships, and reflect on their processes and results.

Reflection is intentionally built into the instructional setting. Mundy, Waxman and Confrey (1984) pointed out that "the capacity for reflection upon previous representations and their constructions [students' construction of meaning] is essential in developing and evaluating more adequate conceptions." One technique for developing reflection is to have students work in pairs and in groups. This change in classroom structure has three important attributes. First, students' verbalization helps clarify understanding and identify confusion. Second, verbalization of their strategies and the reasons for choosing one strategy over another brings about reflection at both a cognitive and metacognitive level. Metacognitive skills, also referred to as managerial skills, are the skills needed to think to use a particualr problem solving strategy, to decide if its use is appropriate, and to monitor its use, either continuing its use or abandoning it at a certain point. Third, having students discuss, debate, and challenge mathematical ideas among themselves creates a shift in the locus of authority over the mathematical material. Students acquire a sense of their own authority and the power of their own logic, rather than vest all authority in the teacher.

The teacher facilitates further reflection on and verbalization of underlying thought processes by the skillful use of non-directive questions. Probing questions, in contrast to leading questions, invite students to focus on the sometimes subtle choices they are making and the reasons for making these choices. The goal is to help students make their thinking explicit and develop their metacognitive skills. Such questioning is useful not only when working with an individual, pair or group of students, but also when facilitating a whole-class problem solving session. With its focus on students' thought processes, rather than right answers, this form of questioning also reinforces students' own authority and contributes to erasing the vision of the teacher as all-knowing answer giver.

Leading questions, on the other hand, suggest particular strategies, thereby limiting the metacognitive development of the student. Students who have been led through the problem solution as a result of the teacher's leading questions often meet with frustration when attempting to work similar problems on their own. Students frequently explain poor test or homework results, "I can do it when you're asking me questions, but I couldn't do it by myself."

In the cases where the assigned task proves too difficult for the student, the teacher offers subtasks rather than solutions. These subtasks, which demand a smaller increment in understanding, allow students to still build their own understandings rather than being told how to do it by the teacher. The teacher designs learning tasks which challenge the students to resolve conceptual difficulties or alter misconceptions.

Principles of Teacher Education

It is not sufficient for a teacher education program to feature innovative curriculum and methodologies. The ultimate test of any teacher education program is whether the teachers implement these innovations in the classroom. Research shows that teachers teach as they were taught, not as they were taught to teach (Jones, 1975). Therefore, innovative teacher education programs must devise ways to compete successfully with the years of prior teacher modeling and the institutional pressures to maintain the status quo. The two principles of teacher education that follow seem to have such potential.

1. Teach as you would have teachers teach.

In order to have maximum impact on teachers approaches to mathematics instruction, teacher education should consistently model the type of instruction being advocated. (King, 1980). Teachers need to experience the role of mathematics learner, consistent with the constructivist view, before they are ready to facilitate such learning among their students. This means that the teachers must be challenged at <u>their</u> level of mathematical understanding and problem solving ability. In many teacher education courses, hands-on experience means trying out student lessons (i.e., completing tasks that are given to school children). For teachers with strong mathematics backgrounds, this is little more than familiarizing themselves with the lessons; little or no conceptual learning or expansion of problem solving skill is taking place for the teachers. In contrast, teachers who are challenged at their own levels, who are confronted with mathematical concepts and problems that they have not encountered before, increase their mathematical knowledge and experience the depth of learning that can take place in a learning environment that fosters students' constructions of mathematical ideas.

In addition to teaching mathematics based on a constructivist perspective, the entire program for developing mathematics pedagogy should employ a constructivist approach. The most effective teaching strategies should be used, not only in school classrooms, but also to facilitate teacher learning. Therefore, in using a constructivist approach, teachers are encouraged to develop new understandings of learning, to reflect on their past mental models of teaching, and to build more effective models based on their experiences in the program.

2. Provide Follow-up, Supervision, and Support

Translating one's learning in an inservice course into new approaches to operating in the classroom can be extremely difficult. Pressure to cover an existing curriculum, lack of institutional support, resistance from students, and demands on teachers' time all may reduce the actual effect that inservice programs have on mathematics instruction. Implementation efforts may be put off indefinitely. Initial efforts that do not meet with instant success (the norm rather than the exception) are often abandoned. A greater impact may be realized when programs integrate clinical supervision of classroom practice with methods courses (Simon, 1984).

Hall et al (Hall, Loucks, Rutherford and Newlove, 1975; Hall and Loucks, 1977) have demonstrated that the implementation of classroom innovations does not take place all at once, but rather occurs in several stages. This often overlooked developmental process was described by the researchers:

> Before actual use, the individual becomes familiar with and increasingly knowledgeable about the innovation. First use is typically disjointed, with management problems quite common. With continued use management becomes routine, and the user (teacher or professor) is able to direct more effort toward increased effectiveness for the clients (learners) and integrate what (s)he is doing with what others are doing. Obviously, these advanced levels of use are not attained merely by use of the innovation through several cycles. Experience is essential but not sufficient to insure that a given individual will develop high-quality use of an innovation (Hall, Loucks, Rutherford and Newlove, 1975).

The researchers went on to emphasize the importance of support for the innovation "extended across several cycles of use." It is important to provide supervision/support until the classroom teacher has reached a sustainable level of use of the innovation. Teachers, to be able to make a valuable contribution to the inservice development of others, should be at an advanced level of understanding of and facility with the innovation. (See the description of the Levels of Use in Appendix C.)

Project Goals

1. To assist inservice teachers in developing a constructivist view of mathematics learning and assist them in developing and implementing instructional approaches based on this view.

2. To develop teachers as workshop leaders who will introduce their colleagues to mathematics instruction based on a constructivist view of learning.

3. To provide a useful model for the inservice education of teachers of mathematics.

CHAPTER 2

PROGRAM STRUCTURE

Background

Since 1983, the SummerMath for Teachers Program has been conducting summer institutes to introduce innovative instructional approaches based on constructivism to teachers of mathematics. In the fall of 1984, when the program attracted the interest of local school districts. District administrators and mathematics teachers, SummerMath for Teachers staff, and Mount Holyoke College faculty and administrators began to meet monthly to discuss the potential benefits to local schools of the SummerMath approach.

Early in the discussions, the school districts expressed their need to develop core groups of mathematics teachers who, with appropriate training and follow-up, could become educational leaders in their own districts. The goal of the districts was to develop effective, autonomous, in-house inservice training for their teachers. The districts recognized the significant value of summer instruction programs such as the SummerMath for Teachers Program. However, the group also agreed on the need for follow-up in the classroom to ease the difficult transition from summer training programs to implementing new methodologies. As the discussion progressed, it became clear that a comprehensive program of intensive summertime instruction reinforced during the academic year was necessary to prepare the teachers for leadership roles in their home school districts.

These ideas and objectives became the core of the Educational Leaders in Mathematics (ELM) Project. The ELM Project was designed to meet the needs of teachers as they move from learning innovative approaches for mathematics instruction, to implementing these approaches in the classroom, and finally to teaching these approaches to other teachers in their districts.

The ELM Project, a five-stage inservice program for elementary and secondary teachers of mathematics, extended the work of the Institutes by providing intensive follow-up to assist teachers in implementing innovative educational approaches in their own classes. The ELM Project also selected teachers who completed the Initial Level of the Project (Summer Institute and follow-up) for advanced training to prepare them to conduct inservice workshops in their districts.

Outline of the Program

Initial Level

Stage One: Summer Institute (stipends paid to teachers)

Stage Two: Academic Year Follow-Up (Weekly classroom visits by ELM Project staff plus four additional follow-up workshops)

Advanced Level

Stage Three: Advanced Training Institute (stipends paid to teachers)

Stage Four: Inservice Trainer Apprenticeship (Co-planning and co-leading with ELM staff of school district inservice workshops)

Stage Five: Inservice Training (School district inservice workshops with minimal ELM support)

Description of Program Components

Stage One - Summer Institutes

The Summer Institutes (one for elementary and one for secondary) provided a unified, two-week program based on a constructivist view of learning. This theoretical perspective shaped both the content and the methodology of the Institute. Not only did teachers learn about constructivist theory and its importance for improving mathematical understanding, independent thinking, and problem solving, but they participated in an Institute which was consistently taught from a constructivist perspective. Thus, the learning experience of the two-week Institute served as a model for improving instruction.

Through reflection on their own learning and on the learning of children, teachers were encouraged to question their fundamental assumptions about learning as well as their ingrained patterns of teaching.

The Institute's design was based on the Karplus Learning Cycle (1977). The initial phase of the two-week Institute was spent in experiential/reflective exploration of learning and teaching. Towards the end of the first week, teachers were involved in abstracting underlying principles from their reflections on this exploratory work.

The final week was spent on application. Teachers worked on the development of instructional skills and the development of lessons which were based on the principles of learning that they developed in the first week.

The Institute schedule included three classes each weekday. Conceptual Understanding and Problem Solving took place each morning for three hours; Logo and Computers each afternoon for two hours; and a physical education class followed lunch for an hour and fifteen minutes. Each of these classes is explained in the following section.

Conceptual Understanding and Problem Solving

During the first few days of this class, ELM staff taught mathematics to the participating teachers. This allowed the ELM staff to model mathematics teaching consistent with a constructivist view of learning and gave the teachers an opportunity to learn mathematics in a classroom where construction of meaning was valued, encouraged, and directly planned for. The mathematical concepts chosen were related to the content covered in either the elementary curriculum or the secondary curriculum, but chosen to be challenging to the teachers involved. This was not a simulation, but an actual opportunity for mathematics learning.

These mathematics lessons, which sometimes carried over from one day to the next with homework assigned in the evening, were followed by individual and large group reflection. Individual reflection was in the form of journal writing (discussed below), and group reflection was facilitated by a staff member. Reflection focused on the experience of learning, on the structure of the lesson, and on the roles of students and teacher.

Toward the end of the first week, after participants had spent several days in mathematics lessons, they were asked to synthesize their reflections to be able to describe to the group the understandings of learning and teaching that they developed from the week's work. These syntheses were shared in the large group through brainstorming and discussion. A staff member facilitated this process and provided vocabulary for a number of the concepts of pedagogy identified. Emphasis was placed on the importance of working from the concrete to the abstract (or known to the unknown) and on the construction of understanding by the learner. Teaching methods that had been experienced including small group work, use of alternate representations, and teacher as facilitator (rather than lecturer) were discussed.

The next phase of the program focused on students' learning. Through facilitated discussions of videotaped interviews, teachers had the opportunity to focus on the understandings and the misconceptions of students. They were also encouraged to reconsider the principles of learning and teaching that they had developed in the Institute in light of the misconceptions (or lack of understanding) exhibited by the students in the interviews. This work was followed by work in triads to develop teachers' abilities to ask probing (non-leading) questions. Such questions get students to be reflective and explicit about their thinking and methodology. Probing questions, as contrasted to leading questions, do not provide metacognitive clues to a problem solution. This phase of the program was designed not only to develop skill in probing questions, but to help make teachers more aware of when they wish to ask a probing question versus a leading question, and the consequences of each.

This work was followed by two opportunities to interview a student one-on-one. The first interview was designated as a time to assess the mathematical understanding of the student, to find areas in which the student seemed to have a solid understanding and areas where the student's understanding was weak or involved misconceptions. After individual, pair, and large group reflection on this experience, a second interview took place with the same student in which the teacher attempted to work on one area of weak understanding, using what they identified as their new tools based on the Institute work. Again, this phase was followed by reflection.

The final phase of the Institute involved a series of tasks designed to develop teachers' abilities to plan constructivist lesson sequences. Teachers were involved in designing problems to assess understanding; identifying key concepts, subconcepts, and prerequisites; designing initial tasks to build on the mathematical or world knowledge of the student; designing activities which link these more concrete activities to abstract concepts and symbolism; and finally, selecting activities that require application and extension of the abstract concept. Lessons for the primary grades tended to be restricted to the more concrete end of this spectrum of activity.

Lesson sequences were developed in small groups of teachers from the same grade level. They were shared with a larger group of colleagues and staff for the purpose of critiquing and feedback.

The final morning was spent discussing practical issues and specific considerations for implementing some of these principles of learning and teaching in the classroom. Particular emphasis was placed on reasonable first steps, developing one's own classroom practice before attempting to influence other teachers, and realistic expectations of initial success.

Logo and Computers

The Logo and Computers class served two purposes. The first was to provide an additional, ongoing opportunity for teachers to learn new concepts in a constructivist learning environment. The second was to give teachers hands-on experience of computer tools and environments which can be used in the construction of mathematical concepts and the development of problem solving abilities.

Logo, the educational computer language, was taught for two weeks to elementary teachers and one week to secondary teachers. It was chosen because of its appeal and accessibility to students, because of its rich potential for the development of geometric and functional relationships, and its usefulness as a problem solving environment.

Secondary teachers spent the second week of the computer class working with mathematical software, particularly the Geometric Supposers and graphing packages. They were provided with lessons which encouraged the use of this software for exploration and the generation of hypotheses.

The computer class concluded with a reflection on the types of learning that took place and the specific potential that such computer environments have for implementation in the classrooms of the teachers involved.

Physical Education Classes

Each teacher who was not prevented by physical disability participated in one week of jazz dance instruction and one week of tennis instruction. Instruction was provided in classes of approximately eighteen teachers.

The physical education class served two main purposes. First, it provided a break from the mental demands of the academic classes and the intense emotional demands on participants who were taking a hard look at the teaching that they do and have done for an average of seventeen years. (This process of reflection can be a painful one at times.) Second, it contributed to the overall goal of having teachers reflect on learning. Dance and tennis classes gave the teachers an opportunity to reflect on the learning of new skills (physical skills), adding to their overall understanding of learning. They also gave teachers, who may be comfortable in the domain of mathematics, the opportunity to be novices in an area in which they did not feel as comfortable. Teachers were often able to relate their experience of dance or tennis anxiety to the math anxiety experienced by students in their classrooms.

One teacher's reflections demonstrated the connection:

> Two components of learning, both cognitive and affective, were brought home to me in tennis. I came to tennis as a willing learner who happened to have no major aptitude and a bunch of misconceptions--the situation of many of my students in my classes.

It was not the learning of tennis or jazz dance itself that was the key to this component of the program, but rather the fact that they were embedded in an atmosphere of reflection on learning.

Other Parts of the Program

Pre-Institute Readings

Teachers were sent reading assignments prior to arriving at the Institute. Pre-Institute readings included a review of some of the work of Jean Piaget and readings from Mindstorms by Seymour Papert. Assorted journal articles began to get teachers thinking about some of the key issues of learning and teaching, while not explicitly describing the concepts and principles that teachers would hopefully construct during the first week of the Institute.

The Journal

Throughout the program, teachers kept a personal journal which was used as a principal instrument for reflection on all phases of the Institute experience. They were asked to begin the journal before they arrived at the institute with a discussion of their beliefs about how mathematics is learned and how it should be taught. During the institute, they recorded their thoughts and reactions each day. At the end of each week, the journal was collected and read by the project staff. However, teachers had the opportunity to fold over any pages that they did not want read. No evaluation or comments were made on the journals.

Synthesis Papers

At the end of each week of the Institute, teachers wrote a synthesis paper pulling together their learnings from that week at the Institute. Journal entries from before and during the Institute provided much of the raw material for these syntheses. Program staff read and responded to the papers.

Evening Assignments

During the Institute, a minimum of additional readings were provided following relevant activities. Teachers had mathematics work to do during the first few days. They also had planning tasks to do outside of class during the second week. Following the interviews, teachers were asked to listen to their interview tapes, reflect on them, and to work with a colleague in providing feedback to each other on the interviews.

Guest Presenters

Women and mathematics. Although it has been suggested that constructivist classroom structures are better suited than traditional classrooms to the specific needs of female students, constructivism is not in itself a cure. It is even possible that gender-biased classroom dynamics could be exacerbated by the more active involvement of students (e.g., males taking a more active role in small groups). For this reason the topic of women in mathematics was addressed directly. In each Institute, a guest presenter conducted a workshop on Women and Mathematics to heighten teachers' awareness of the dynamics that often take place between males and females and the teacher in classrooms.

Piaget. Throughout the institute, teachers were actively learning about constructivism, Piaget's view of learning. This learning was supplemented through a workshop conducted by a guest presenter. The workshop helped teachers to abstract Piaget's theory of equilibration and to understand the types of thinking characteristic of different stages of development.

Collegial Discussions

An important part of the program was the collegial discussions that teachers had during non-class hours. Teachers were strongly encouraged to be in residence in the dormitory because of the increased opportunity for such activity. Discussions between teachers can provide a partial remedy for teachers' feelings of isolation in their own classrooms.

Stage Two: Classroom Follow-up

The Classroom Follow-up component of the ELM Project provided extensive support and supervision for participating teachers who had completed the two-week summer institute. One ELM staff member was assigned to each teacher. (Staff members' case loads varied from two to eleven teachers.) The staff person visited the teacher's classroom one class period a week and following the class met for a half-hour with the teacher. This weekly visitation took place from September through May.

At the beginning of the year, the classroom teachers chose from what they found valuable in the Summer Institute as a starting place for implementation. The staff member provided feedback, demonstration teaching, opportunities for reflection, and suggestions with the teachers' own goals in mind.

Teachers also attended four ELM workshops (two day-long and two half-day) during the academic year. These workshops allowed for collegial sharing about implementation efforts, hands on lessons related to common concerns, analysis of student learning and misconceptions, and small group planning sessions. School administrators were invited to attend one of the afternoon sessions along with the teachers to become more familiar with the program. An additional meeting was set up for the administrators to deal specifically with administrator involvement.

Stage Three: The Advanced Institute

Following Stage Two, ELM teachers who were interested in participating in the Advanced Level of the Project reapplied. Whereas the ELM grant provided support each year for twelve of the thirty initial level teachers to participate in the Advanced Level, additional teachers were accepted each year with financial support from participating school districts.

The goal of the Advanced Level was to develop teams of in-house inservice leaders for participating school districts. Thus, the Advanced Institute was designed both to further the classroom work of the teachers involved and to provide training for these teachers in conducting inservice workshops.

The Advanced Institute began once again with opportunities for the teachers to be math students and to reflect on these experiences. Efforts were made to carry through instructional units beyond single lessons to give teachers a fuller model of the development of concepts.

Teachers also engaged in analyzing student learning through videotaped interviews.

The greatest emphasis in the Institute was on the development of lesson sequences. Teachers worked in various groupings to plan instruction, receive feedback, and revise instruction. Available curriculum materials which lend themselves to construction of concepts were adapted as part of the planning activities.

In addition to this work, teachers prepared for their work as inservice leaders. They practiced questioning skills, facilitated groups, and conducted sample lessons. They discussed reasonable expectations for inservice workshops and how workshops were different from two-week institutes. An attempt was made to anticipate difficulties and to discuss feelings that teachers had as they contemplated this new role.

Stage Four: Inservice Leader Apprenticeship

During Stage Four, teachers, in teams of at least two, worked with an ELM staff member to plan and lead four inservice workshops. These workshops of approximately two-and-a-half hours were conducted in the teachers' own school districts. Typically, the amount of responsibility taken by the teachers increased over the course of the four workshops.

The planning sessions for these workshops also served as a support system for the Advanced ELM teachers who received no classroom follow-up during this second academic year.

Stage Five: Inservice Leadership

In Stage Five, the teachers from Stage Four provided additional inservice leadership in their districts independent of ELM staff. ELM staff remained available for consultation but did not take an active role in the delivery of the inservice training.

CHAPTER 3

INSTRUMENTATION

In order to assess the teacher development efforts of ELM, available evaluation instruments were used or modified and new instruments were developed. Below are descriptions of the instruments used.

Questionnaires

Questionnaires were designed to provide a mechanism for participating teachers, district teachers who attended Stage Four workshops, and district administrators to evaluate the various components of the program. All questionnaires had open ended questions and Likert-style questions to allow for both qualitative and quantitative evaluation. Copies of the questionnaires are found in Appendix A.

All Institute participants (ELM and non-ELM teachers) filled out anonymous questionnaires at the end of the Institutes (Stages One and Three). A subset of the items, those which dealt with the Institutes' effectiveness in general, were used to provide a numerical evaluation. ELM teachers also turned in questionnaires at the end of the follow-up program (Stage Two) and at the end of the apprenticeship (Stage Four).

In April of 1988, all ELM teachers who had entered the program between 1985 and 1987 were requested to furnish additional information in response to the following questions:

1. What changes have you observed in your students as a result of your involvement in the ELM Project? (Include all types of changes: positive, negative, and neutral.

2. What activities, not directly a part of ELM, have you engaged in that were a result of your participation in the ELM Project? (Please include classroom work, things you have written, leadership, work with other teachers, involvement in other program, curriculum development....)

District teachers (non-ELM) filled out a short feedback form to evaluate Stage Four workshops conducted by ELM teachers and staff.

In April 1988, administrators of all participating districts were asked to respond to questionnaires to evaluate the ELM Project--one for the Initial Level and another for the Advanced Level.

Attitude Surveys

Attitude surveys were created to examine changes in student attitudes as a result of their teachers' participation in ELM. The surveys had two Likert-style components: 1) a set of items about enjoyment of mathematics and the importance of mathematics that were combined to calcuate a general attitude score, and 2) a set of items for which students responded to the following question: "To do well in mathematics, how important are these?" These items provided information on students' conceptions of learning mathematics.

Items from existing instruments (Aiken, 1974 and Schoenfeld 1985) were used or adapted. Additional items were written particularly for the ELM instrument.

Initially the same surveys were given to grades four through twelve. After two years, however, elementary teachers explained that the format and wording of the items were too complicated for young students. A new, simpler version was written for elementary students and administered during the third year of the program. Elementary and secondary surveys were compiled separately.

Copies of the attitude surveys are found in Appendix B.

Standardized Mathematics Tests

Teachers of all grades, one through twelve, administered a standardized test which included single tests at the primary level and tests of Mathematics Computation and Mathematics Basic Concepts in grades 3 through 12. Similar to most standarized tests available, they do an inadequate job of measuring conceptual understanding and problem solving abilities. They primarily evaluate routine and procedural knowledge of mathematics.

Levels of Use and Assessment of Constructivism in Mathematics Instruction

The ELM Project provided the opportunity to identify some of the particular evaluation issues that must be considered when assessing implementation of instruction based on a constructivist perspective.

Evaluating classroom implementation is a step that is often overlooked in assessment of inservice programs. Frequently the success of a teacher development intervention is determined by measuring the impact on the students of the participating teachers. Such an evaluation is based on the assumption that participating teachers have, in fact, successfully implemented new methods and that students' test scores indicate the effectiveness of these methods. However, in order to assess the impact of new teaching methods on students, we must first determine whether, and to what extent, teachers have actually implemented them.

ELM researchers endeavored to distinguish between teachers' implementation of instructional strategies based on experiences in ELM and teachers' development of a constructivist view of learning as a basis for their instructional decisions. The former was designated "strategies" and the latter "epistemology." While the implementation of strategies modeled in ELM was viewed as a significant step, it is the development and use of a constructivist view of learning that was the principal objective of ELM. The following example illustrates the importance of this distinction.

Donald and Eric had each been teaching high school for 20 to 30 years. After a year in ELM, they had each modified their teaching approach in similar ways. They were doing less lecturing, letting students work out problems for themselves in pairs or groups, and having students share their solutions in class discussions. They were both comfortable with and very positive about these changes. If assessment were based soley on the implementation of strategies, the ratings would have been similar for Donald and Eric.

Donald and Eric's classes were considerably different. Donald seemed to be basing his instruction on constructivism while Eric was not. Although their personal styles were in some ways very similar, the two teachers were posing very different types of problems for their students. For example, at the beginning of each of Donald's classes, he posed a question that he had selected to address a particular mathematical concept. He chose the concepts that he felt were significant (choices that sometimes differed from those made by the text book others). His questions challenged students' current understandings, often involving applications based on the their common experiences. At other times the questions built on concepts that had been explored in previous classes, whether days or months earlier. As the discussion developed, Donald listened carefully to his students. Subsequent questions were careful and respectful responses to what his students were saying.

In constrast, the problems Eric posed were selections from the pages of exercises contained in the text book. Problems were chosen according to the editor's classification of difficulty, A, B, or C. He did not base his selection on critical concepts, nor did he focus students on connections between concepts. He listened for students to describe how to perform the problems correctly and his focus never wavered from the anticipated answer. Donald and Eric's instructional methods seemed to stem from different understandings about teaching and learning.

To assess implementation of strategies, ELM adapted the Levels of Use (LoU) measure, developed by Ha et al. (1975). LoU, through structured interviews, assesses the degree to which an innovation has been implemented. The instrument is designed to evaluate use of innovations which are changes in instructional strategies.

To complement the information collected by LoU, the Assessment of Constructivsim in Mathematics Instruction (ACMI) was developed by ELM researchers to assess the extent to which teachers based their instructional decisions on a constructivist view of learning (epistemology). ACMI was modeled on the Levels of Use (LoU) instrument (Hall et al. 1975) and consists of a structured interview and a rating procedure for assessing teachers' responses.

The choice of LoU and the development of ACMI were to meet the following criteria:

1. The instruments had to be sensitive to the developmental nature of the implementation process.

Effective use of new strategies and approaches is achieved through a series of struggles and successes that take place over time. Hall et al (1975) designed an evaluation tool called Levels of Use (LoU) based upon a view of implementation of innovation as a developmental process.

On the LoU rating scale, teachers move from not knowing about the innovation (level 0, "non-use"), to using the innovation with different levels of sophistication (levels III through V). The relevant levels are outlined below. (After an intensive two-week Institute and a year of supervised work on implementation, teachers tend to be either at Level 0 (non-use) or at Level III and above. In the original instrument, levels I and II involve getting information about the innovation and preparing to implement.)

LOU SCALE

Level 0: NONUSE does not use the strategy.

Level III: MECHANICAL USE uses the strategy: struggles with problems of classroom management with respect to the strategy.

Level IVA: ROUTINE has incorporated the strategy and worked out any mechanical problems

Level IVB: REFINEMENT fine tunes strategy to meet the specific needs of students.

Level V: INTEGRATION assists colleagues with implementation of the strategy or collaborates with them in implementing the strategy.

At level III. "mechanincal use." teachers have started to use the innovation. but are focused on problems of management. For example. a teacher whose main focus is the most efficient way to distribute manipulatives or to keep students' noise levels down would be at this level.

At level IVA. "rou.ine use." teachers are no longer struggling with management: implementation of the innovation runs smoothly. At level IVB. "refinement." teachers begin to revise the innovation to meet the specific needs of students. The teachers' shift from IVA to IVB reflects a change of focus from teaching behaviors to the students needs (learning).

In the LoU interview. teachers are asked to describe how they are using the innovation. what they see as its strengths and weaknesses. and what plans they have for future use of the innovation. The developmental stage is assigned according to the teachers' descriptions of their own practices.

2. The Instrument had to be consistent with the program's commitment to let teachers set their own agenda for implementation.

In order to use the LoU instrument. it was necessary to define what constitutes use of the innovation. However. the ELM Project was committed to having teachers define their own learnings. set their own goals. and work with what was important to them. ELM teachers made a variety of implementation choices based upon their own personal styles. the different learnings that they developed. as well as the grade levels and cultures of their classes. As a result.

their classrooms looked very different from each other. In September, one teacher might choose to focus on using manipulatives, another on working in pairs, and another on listening to students verbalize their thought processes. Some teachers committed themselves to one day a week of problem solving, and others immediately integrated new methods into the daily curriculum. As the year progressed, they modified their objectives. However, their efforts remained diverse.

The evaluation tool had to be flexible enough to allow for such variation. ELM staff generated the following list of strategies that had been modeled consistently during the Summer Institutes.

Strategies Modeled in ELM

1. Using non-routine problems
2. Exploring alternative solutions
3. Asking non-leading questions
4. Using manipulatives, diagrams, and alternative representations
5. Having students work in groups and pairs
6. Pursuing thought processes on both "right" and "wrong" answers
7. Working with Logo
8. Employing wait time
9. Encouraging student paraphrasing of ideas expressed in class

During the LoU interviews this list of strategies served as a guide for the interviewers, but was not seen by the teachers. Levels of Use were determined for teachers who described use of one or more of the strategies on the list, based on the strategy of highest level of use.

The ACMI assessment made use of the same interview as the LoU by including some additional questions. It was necessary, therefore, for the interviewer to ask questions which got beyond the strategies being employed. Basing instruction on constructivism involves changes in thinking and belief. Asking the teacher directly about beliefs, however, was unlikely to yield reliable data. We wanted to avoid measuring how well teachers could articulate philosophical perspectives or how closely their vocabulary matched our own. Yet, we did want to assess the epistemological framework from which they were operating in the classroom.

To get at teachers thinking and conceptualizations of learning, we expanded our interview questions to ask teachers to describe how they went about planning a new topic. Through the descriptions of their own processes, prompted by probing questions from the interviewer. additional data became available on the teachers primary concerns and the nature of the decisions that they made.

In order to rate this data, the evaluators needed a precise, working definition of constructivism, the innovation being evaluated. We settled on the following two-part definition:

1. Constructivism is a belief that conceptual understanding in mathematics must be constructed by the learner. Teachers' conceptualizations cannot be given directly to students.

2. Teachers strive to maximize opportunities for students to construct concepts and minimize teacher telling and student memorization and immitation. This suggests not only a perspective on how concepts are learned, but also a valuing of conceptual understanding.

The ACMI is based on the belief that a change must take place at the level of one's theory of learning. It is this theory that directs decisions about instruction. The assumption is that each teacher develops a unique and evolving epistemology. Evaluation in this category determines whether the epistemology inferred from teachers self-reports can be characterized by the definition of constructivism, above.

The ACMI has levels which correspond to the LoU scale.

ACMI Scale

Level 0:	does not have/use a constructivist epistemology.
Level III:	attempts to modify instruction based on a general view that instruction should involve students in active construction, struggles with how to integrate this view with teaching style and curriculum
Level IVA:	has modified teaching style to include regular active construction by students, focuses primarily on teaching behaviors.
Level IVB:	focuses on student learning rather than teaching behaviors to shape instruction from a constructivist perspective.
Level V:	assists or collaborates with colleagues to implement instruction based on a constructivist view.

The original LoU scale reflects a pattern of implementation (Levels III - IVb) that progresses from mechanical use of a prescribed behavior to the teachers ownership of the ideas behind the behavior (Level IVB). In a program that was designed to provide teachers the opportunity to reflect on learning and the role of the teacher in order to construct a new personal epistemology, this pattern of implementation did not fit. The rating scale had to reflect a developmental pattern consistent with what we were observing in participating teachers. Teachers seemed to leave the Institute with a rudimentary epistemology consisting of some general views on learning and worked to develop their own set of behaviors for putting those ideas into action. Therefore, the developmental process was reversed. Instead of moving from particular behaviors to personal commitment (use of strategies), teachers seemed to progress from a personal and general commitment to specific implementation ideas (use of epistemology).

In ACMI Level III, teachers have a general, and usually not very deep, understanding of constructivism, but for the most part, it is not operational (they are trying to find a way to implement that understanding in the classroom). For example, a teacher might feel that it is important for students to construct mathematical ideas. Therefore, rather than telling them the ideas, she begins to ask the students to solve problems and come up with the ideas. At this point, the teacher has not developed a comprehensive scheme that suggests where to start with the student in this process of construction, nor how to structure the student's work for optimum learning. A teacher at this stage struggles with how to reconcile new ideas with the curriculum, textbook, etc. The teacher often focuses on how to "be a constructivist teacher" and often neglects to focus on student learning as the basis for instructional decision making.

Level IVA which is defined as 'routine use" required only a moderate change from the LoU IVA. At this level, teachers have become comfortable with more active involvement on the part of students and with a new teaching role that involves less telling. There is a sense that their teaching behaviors are consistent with constructivism.

Level IVB in the original scale is characterized by an attention to the learning needs of the students. Teachers who are using a constructivist epistomology at Level IVB are beginning to fine-tune their lessons. They are able to monitor student learning and understanding and revise their lessons, putting in intermediate steps, extending applications in certain directions, and confronting misconceptions. Teachers at Level IVB have a rationale for making decisions and as a result are much less concerned with what they "should" or "should not" do as "constructivist teachers." In constrast to Level III and IVa, the focus is on student learning in particular--not just teaching behaviors which generate student-centered lessons.

While the two categories (epistemology and strategies) are rated independently, development in these two areas should not be construed as independent. Use of constructivist epistemology informs the choice of and necessitates the use of appropriate strategies. Initial use of strategies, particularly when enhanced by the reflection on resultant student learning encouraged by the follow-up consultants, often results in the development of or solidification of constructivist epistemological views.

CHAPTER 4

RESULTS AND DISCUSSION

Inservice programs are geared toward effecting change in already-existing institutions as well as in the individuals who comprise them. Thus, evaluation of an inservice program must be conducted at several levels. Specifically:

1) Impact on Teachers
2) Impact on Instructional Practice: Classroom Implementation
3) Impact on Students
4) Impact on Districts

Impact on Teachers

Teachers' Writing and Evaluation Questionnaires

Stage One: Initial Level Institutes

During the three summers of the ELM Project, 1986 through 1988, separate two-week Initial Level Institutes were conducted for elementary and secondary mathematics teachers. Thirty-six teachers were admitted to each of the Institutes. (Prior to one of the six Institutes, one teacher dropped out at the last minute, resulting in enrollment of 35.) Of the 72 teachers attending each summer, 30 were Stage One ELM participants, approximately one-third secondary and two-thirds elementary. The remaining teachers came from all over the country and were not supported by the grant.

In the synthesis papers for the Initial Level Institutes, teachers were asked to consider their experiences of the week and reflect upon how these experiences affected their views of learning and teaching. Segments from these papers provide a sense of the teachers' experiences and reflections which they identified as significant.

When teachers developed new ideas about learning and teaching, they tended to develop a more critical perspective on their own past practices.

> Having been a third grade teacher for the past seventeen years, it is somewhat disconcerting to come to the realization that I have not been providing my classes with the optimum learning experiences in math.

> My methods over the years have been fairly traditional. I presented new math concepts in various ways, such as using the overhead, drawing symbols on the board, etc. I provided much practice in computation. I programmed them with many rules or tricks for computation and for solving word problems, so that many of them even became quite proficient. But only a few very capable children could tell me why they were doing what they were doing. This is clearly not the way math should be taught.

> When I think back to my undergraduate, post graduate, and teaching days, I realize that an unfortunate thing has happened. This math institute has brought me to this realization. That is, I was taught good sound practices of teaching math. However, when it came time for me to teach math, I didn't carry this knowledge through with me. Being put back into the role of a learner, I now realize that if I had stuck to my early learnings, things could be different. This institute has brought me back to my college days, and hopefully will allow me to put some very unsound math teaching practices to rest.

As implied in the last paragraph, being in the role of mathematics learner had a profound influence on the thinking of many participants. The following statements illustrate the variety of the lessons learned from these model mathematics lessons.

> Every aspect of each day has put me into the shoes of a learner. No wonder my kids groan at the thought of solving problems. I mentally groaned at the beginning when told I was going to do the same. It's very unpleasant when not done correctly. Now I realize that when a learner has to search for possibilities, try strategies, discard incorrect solutions, use manipulatives, and cooperate that problem solving is exciting and worthwhile.

> I wasn't told what to do, but was allowed to search.

> After this first week of being a learner, I am much more aware of a learner's needs. The anxieties, successes, failures--emotional roller-coaster I've been on--have made me much more sensitive to the child.

> Seeing how this type of learning took place in this institute shows me it can be done.

> Personally experiencing learning in the context of these concepts has been a powerful motivator and has changed what I held as attitudes and beliefs to commitments for action.

Being a learner in the mathematics lessons stimulated important changes in many teachers' relationships to mathematics. Some elementary teachers, who had come with a history of mathematics avoidance and mathematics anxiety, addressed this change.

> Something else that was very important to me was the excitement of discovery coming from within myself. I have always had the satisfaction of "doing it myself" and being successful in other areas--but not really with math. These feelings had most often eluded my encouters with math.

> I have come to the conclusion that I am not as poor in math as I once thought, but rather I was not given a sufficient understanding in the first place. For example, I worked with different number bases in a college math course. I was totally lost and never really understood the material. Working with the manipulatives in class I was able to see the concept immediately.

> I have found the experiences of this week very rewarding and helpful to me as both a learner and a teacher. I realized as I worked through the math problems that I felt more empowered than I think I ever have felt before in mathematics. That is not to say that I feel totally confident about math. But I realize that I have ways and means to approach solving a problem and because of that I have more willingness to do so. I'm finding mathematics somewhat less intimidating and more exciting and fascinating.

Most teachers arrived at the Institute without having deeply considered the question, "How do people learn mathematics?" In general, teachers teach as they were taught. Through their Institute experiences, they began to develop new personal theories about learning.

> I'm afraid I had never given a lot of thought as to how children learned math, or even, actually, what was really meant by learning math....Since I have had the opportunity to be a learner for the past week...it has become obvious to me that in my math classes many children were not actually learning, but were being programmed with information. Processes were being memorized but not understood.

> This increased sensitivity has changed my belief about how children learn. They don't learn best when they are regurgitating what I've taught them but rather when they teach themselves with my guidance.

> What I had thought of as a part of math (problem solving) I realize now is in fact the essence of teaching math.

> Instead of listing on the board, as we usually have done, the topics for the lesson and then teaching a method how to do it--it happens (or now should!) really the other way around. The student (class) works finding the rule, discovering the topic, making his or her own previously acquired understandings come together and connect to the task at hand.

By the end of the Institute, most of the teachers were taking a hard look at the prospect for change in their own schools.

> I feel, as a teacher in the classroom, I was hung up on accountability, afraid to deviate from what I had done in the past and reluctant to take a chance to experiment at the expense of a child without knowing for sure just how to go about it.

> I'm committed to change for myself and my students. I'll be trying to keep an open mind, and have some fun with math....I'll be willing to try new techniques, but will be patient with myself and my students.

> After these two weeks at SummerMath, I realize that the process of becoming a better teacher (in my new definition) is a long, continuous growth. The trouble I see for myself is in isolating single [goals], not trying to do everything at once.

> I want to develop (eventually) a whole 7th grade curriculum based on fractions, but right now my first step is to develop in my own mind a first step!

> I will return to work in the Fall with a qualitatively different framework in which to plan activities for children. I will be examining the way I ask and answer questions, the way I structure lessons, the very way I respond to a child's need for mastery. But more than this, I will be a learner myself, seeking mastery over the problems that teaching presents.

The evaluation forms that teachers filled out just before they left the Institute consisted of a set of specific opinion statements that teachers rated and a set of more general questions that solicited comments. A score for overall effectiveness was obtained by averaging mean scores of six Likert-style items. For all six of the Initial Institutes, this calculation yielded an overall score of between 4.1 and 4.5 (where 5.0 is a maximum score).

Responses to open-ended questionnaire items amplified the meaning of these scores. Teachers remarked: "It made me re-think and re-evaluate everything I do in teaching math." "I'm excited about making math more meaningful, more fun, and more directly related to experience." "My teaching will change because there has been a change in my way of thinking." "I can't wait to have the opportunity to put my new ideas into practice." "Everything from my philosophy to my attitude towards students to specific implementation ideas has been affected by these two weeks."

Many of the teachers' comments reflected a deepening of their sense of what teaching is. For example, one teacher wrote,

> I am very anxious to implement some of these strategies in my classroom. It is my desire to be a better teacher and I believe that means I must be more conscious of my students' understanding....What I've been doing in the past has been the easy way. Now I realize that I face an awesome responsibility in living up to the goals I've set as a result of my SummerMath experience.

Several teachers also reported that they had needed a "shot in the arm." "Arrived here down on teaching. I now have renewed spirit and enthusiasm." "Really rejuvenated my interest in teaching." "I feel the excitement of a new beginner....That's pretty good after nearly 20 years in the same system."

Negative responses, which were much fewer, tended to focus on the intense pace of the Institute and the lack of free time. Teachers commented:

> I thought of the armed services and moonie-systems where people are kept very, very busy--get tired--are kept very busy and are indoctrinated. I am not suggesting that this experience has been horrible, or parallels those extreme instances, but there are parts that have a strand of those.

> I felt like I was in boot camp.

Stage Two: Academic Year Follow-Up

During three academic years, Stage Two ELM teachers were visited by ELM staff members on a weekly basis for observation and consultation. Fourteen teachers completed Stage Two during 1985-86, twenty-nine teachers in 1986-87, (one teacher dropped out because she did not feel that her participation was worthwhile), and twenty-nine teachers in

1987-88 (one teacher dropped out because of illness in the family).

On a set of 16 questionnaire items to which teachers responded strongly disagree, disagree, neutral, agree, or strongly agree, the average response each year was between 4.1 and 4.5, where 5.0 was the maximum score. (The ratings of negative items were reversed to calculate the average score.)

The one item that scored below 3.8 was, "The follow-up program has caused me anxiety," which had a mean score of between 3.0 and 3.3 as well as the largest standard deviation. Several teachers, however, wrote comments to qualify the item, saying that they were anxious only at the beginning of the year or that the anxiety caused them to work harder.

The evaluation questionnaires also included open-ended questions. We shall report here the responses of one teacher, for they include many of the points made by other teachers:

What effects has your participation in SummerMath for Teachers had on your teaching and your students' learning?

> [I have] made modifications in content, have focused on more basic underlying concepts instead of just the surface level knowledge and problems in the text book. Have made a conscious effort to analyze material being presented and how it fits in with the structure or proof, knowledge, and previous material. Have many more class periods devoted to students working and me as a consultant than before--very hard for me to judge long range goals in students' work.

What difficulties have you experienced in trying to implement what you learned in the program?

> I feel I make many compromises between the reality of the teaching environment (time for me to think, plan and make materials, time for students to progress through the book, grading system and school schedule) and the intellectual concepts of how people learn things. Sometimes I am frustrated by the sheer variety of learning that occurs in the classroom of 25 folks, and am not sure what to do with it all.

> The thing I like best about the Follow-up Program is:

> It is every week--I enjoy the chance to reflect on what has been going on during the previous time. It provides me with a focus. A time is set aside for

thinking about what I wanted to accomplish. Would that happen without the weekly meetings? I fear the time would be spent doing other things.

The thing I like least about the Follow-up Program is:

it is every week! There are times I feel unable to use the resources available. I'm not sure what it is I want or how to get it!

Comments:

The Follow-up Program does put a sense of pressure on me to perform, but this is balanced by the attitude I have that I want to perfrom better in these ways. So the pressure, while real, is a positive force.

The only negative comments on the classroom follow-up were made by a teacher who had a clash with her consultant. This teacher, however, continued to value the ELM experience and recommended the program to her colleagues.

Teachers reported that the four workshops conducted during Stage Two were also an important part of the program. They found that the focus of the workshops was different from the weekly visitations. Whereas the weekly visitations often centered on the day's lesson, the workshops provided an opportunity to reflect on and assess one's efforts more broadly.

Stage Three: Advanced Institute

Advanced Institutes were held during the summers of 1986-88. 20 teachers (8 ELM) attended the 1986 Institute; 26 teachers (17 ELM) attended the 1987 Institute; and 25 teachers (14 ELM) attended the 1988 Institute. Each year, more teachers were interested in the Advanced Level of ELM than the number of slots provided by the grant. (NSF funded 6 slots the first year and 12 for each of the two following years.) To continue the involvement of talented, engaged, and excited teachers, participating school districts were asked for funds for the additional teachers. All of the districts whose teachers were involved agreed to share payment of the balance. In addition, several districts supported Initial Level ELM teachers who wanted to attend the Advanced Institute for their own development, but who chose not to participate in Stages Four and Five.

In their papers for the Advanced Institute, teachers were asked to describe their current models of learning and teaching. Many of them also discussed the processes by which these ideas had evolved. In contrast to the Initial Level Institute in which teachers were confronted with many questionaires. (Filling out questionaires was the least favorite activity of ELM participants.) They reported that their involvement in the workshops helped them to clarify their own ideas about constructivism and strengthened their commitment to teaching methods that fostered student constructions of mathematical ideas. "Those who teach others, learn the most," one teacher wrote about her Stage Four involvement. They also said that the preparation meetings were an important source of support as they continued to implement new methods in their classes.

Some teachers said at the end of the year that they still felt unqualified as workshop leaders. Most, however, said that they had initially been nervous about conducting workshops for their peers, but now they felt that it was worthwhile and enjoyable. One teacher even wrote, "I was somewhat nervous at first, but felt elated by the fourth workshop at responsiveness of the group."

In April 1988, one participant, who was also an administrator (department chair), responded in depth to the questions for district administrators. His statements trace his experiences through all the stages of the project.

> [STAGE ONE] I thought before attending the institute, that the only way to improve one's skills was to take more math courses. I was dead wrong. The summer institute introduced me to a most important facet of teaching, one that I hadn't realized before. And that is simply that with the appropriate strategies students can participate from the beginning of an idea. For example: In the past, I have introduced the concept of a logarithm in such a way that properties like
>
> $$\log xy = \log x + \log y$$
>
> were spoon-fed to the students. As a result of the institute, I have discovered that groups of students working together can make conjectures based on minimal information and end up hypothesizing relationships that included the following
>
> $$\log x = -\log 1/x$$
>
> $$\log xy = \log x + \log y$$
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> These relationships are the heart and soul of the logarithm and my students were involved in the discovery. This I believe is true problem solving.
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[STAGE TWO] The weekly consultations were very useful. My mentor encouraged me to identify the strategies that I wished to use. Her criticisms were centered on how well the strategies were employed and never once could be perceived as dictatorial.

In the end I began to encourage others in the department to analyze their methods and see if they couldn't begin to involve their students earlier in the unfolding of new mathematical concepts.

[STAGE THREE] The summer institute brought us together again for another round of problem-solving and evaluation of strategies. Once again it was proved that students who can share ideas and have opinions in an appropriate atmosphere will gain confidence in their abilities and will have an eagerness lacking in more traditional classrooms.

[STAGES FOUR AND FIVE] The workshops did show-case strategies to our [school district] staff. Some come with open minds. Others don't. Some have no confidence in their own abilities. But an interesting change has occured. My participation has made it easy to introduce a rather revolutionary geometry program centered around a piece of software called the "Geometric Supposer." It became clear that this software epitomized all of the ideas in the two institutes. It requires student participation from the onset of a new idea. It demands that conjectures be made. Data collected and shared with the class. And finally substantiation of the conjectures.

The teachers involved in the [Geometric Supposer] program are beginning to see applications of these strategies to other subjects they teach. I believe we are moving forward and I also believe that it would not be so if it weren't for my participation in the ELM Project.

Other Activities

Several years into the program, ELM staff became aware that many teachers had become involved in professional activities not directly related to the ELM project. In order to document this and investigate its relation to ELM, letters were sent (April 1988) to sixty-one teachers (twenty-nine current Stage Two teachers and thirty-two Advanced Level teachers) asking the following question:

"What activities, not directly a part of ELM, have you engaged in that were a result of your participation in the ELM Project? (Please include classroom work, things you have written, leadership, work with other teachers, involvement in other programs, curriculum development....)"

Thirty-five teachers responded in writing. Following is a list of activities which were reported. The number of teachers reporting the activity is in parentheses.

worked on or rewrote mathematics curriculum (23)

shared new ideas with other teachers (23)

attended (non-ELM) workshops and/or conferences (11)

gave talks or led (non-ELM) workshops (9)

changed teaching methods in other subjects (9)

established a teacher-support group (8)

wrote an article or paper (7)

became a curriculum committee member (6)

took other courses (6)

taught new courses (4)

joined a Master's degree program (2)

received a Horace Mann Grant (2)

became a Lucretia Crocker Fellow (1)

Discussion of Impact on Teachers

Teachers' feedback as well as their writings have indicated that ELM Project experiences have had a substantial impact on their view of education and on their teaching. The changes that were produced began in the first Summer Institute. Teachers reported that these changes occurred in their views of how children learn, their conceptions of mathematics, their experience and feelings about doing mathematics, and their ideas about what constitutes good teaching.

Teachers reported that the Academic Year Follow-up was an essential part of the change process. They pointed to the need to have someone to talk with for regular ongoing support, for modeling of teaching from a constructivist perspective, and for feedback and suggestions. Many indicated that they would have been unable to sustain the effort without the regular visits of the ELM consultant.

Some of the teachers reported that the consultant's visits caused them anxiety. Although consultants worked very hard to reduce anxiety by encouraging open communication and creating a non-evaluative framework for their visits, some teachers continued to feel some anxiety. The combination of having another professional observing in the classroom, the perception of the observer as the "expert," the desire to "perform well" for the consultant, and their past experiences with observations for evaluation purposes probably contributed to the discomfort felt by some of the teachers. For some, the anxiety decreased or disappeared over the course of the year.

Teachers reported that the four workshops that were held during Stage Two were also valuable opportunities to reflect and deepen ideas. They stressed that the communication with other participating teachers offered support, a sense that their struggles were shared, and an additional source of ideas.

Following the Initial Level of ELM (Stages One and Two), a significant number of teachers applied for the Advanced Level (Stages Three to Five), even though the Advanced Level required a large commitment of time and effort. Teachers reported consistently that Stage Three, the Advanced Institute, was an important step in their development. It was important to have another institute experience after a year of implementation efforts, and many of the ideas that they had been wrestling with had come together and become more fully operational.

Leadership in the Stage Four workshops was an important next step for the teachers. First, it was an opportunity for them to continue to develop their own ideas as constructivist teachers. Second, the new role as leader was stimulating and rewarding for most. Some teachers, however, even at the end of Stage Four, did not feel confident of their abilities to conduct district inservice workshops.

Teachers reported that they began to participate in a variety of activities that were stimulated by the ELM Project, but went beyond the project's design. They continued to pursue a variety of professional endeavors--working on curriculum for themselves, to help colleagues, and for the school: giving talks, leading workshops, and teaching new courses; writing articles for newsletters; taking other courses; beginning a new degree program; and establishing support groups among teachers in their districts.

Impact on Instructional Practice: Classroom Implementation

The results in this section reflect LoU and ACMI ratings from the two full years of the project (data collected in Spring 1987 and 1988). Data from the pilot year is not included because of the smaller number of teachers and because the pilot year was a developmental year for the assessment instrument as well.

LoU results (see Table 1 below) indicate that 98% of the teachers who completed the classroom follow-up implemented strategies modeled in ELM (those listed in Chapter III). Level IVb, which indicates not only stable use but internalization of the innovations, was achieved by 52% of the teachers with respect to these strategies.

According to the ACMI results, 64% showed evidence of at least a rudimentary constructivist view of learning as the basis for their teaching (Level III or above) while 41% were facilitating the constructions of their students by focusing directly on student learning (Level IVB or higher).

Percentages for the end of Stage Four, in contrast to those for the end of Stage Two, reflect selection of teachers (usually self-selection) to continue in the program as well as further development in implementation. To examine the effect of the Advanced Level of ELM (Stages Three and Four), we compared the LoU and ACMI scores of the Stage Four teachers from 1988 with the same teachers' scores from 1987. The results appear in Table 2.

Participation in the Advanced Level seemed to support teachers' development as measured by ACMI (e.g., 40% to 87% at Level IVB). Since this group was selected because of their enthusiasm for the progr m, no appropriate controls were available. Therefore, it s not possible to compare the effects of the Advanced Level on these teachers with an equivalent group of ELM teachers who had an additional year of experience without participating in Stages Three and Four.

Discussion of Impact on Instructional Practices

Evidence from the ACMI interviews indicated that teachers were not only implementing strategies learned in the Institutes, but many were making nstructional decisions based on a constructivist view of learning. As expected, the changes in teaching strategies were more easily and more rapidly made than changes in the epistemological basis of their teaching.

TABLE 1.
SUMMARY OF LOU AND ACMI RESULTS
(End of Stage Two)

Level	LOU (Strategies) #	LOU (Strategies) %	ACMI (Epistemology) #	ACMI (Epistemology) %
0	1		20	
III	10	(98%)	6	(64%)
IVA	16	(80%)	7	(54%)
IVB	21	(52%)	21	(41%)
V	8	(14%)	2	(4%)

n=56

refers to the number of teachers at that level.
(%) refers to the percent of teachers at that level or higher.
Based on interviews in the spring of 1987 and 1988.

TABLE 2. COMPARISON OF RESULTS FOLLOWING STAGES TWO AND FOUR
(LOU AND ACMI)

	Group B-1987				Group B-1988			
	LOU (Strategies)		ACMI (Epistemology)		LOU (Strategies)		ACMI (Epistemology)	
Level	#	%	#	%	#	%	#	%
0	0		2		0		1	
III	2	(100%)	3	(87%)	0		1	(93%)
IVA	4	(87%)	4	(67%)	1	(100%)	0	(87%)
IVB	7	(60%)	6	(40%)	2	(93%)	2	(87%)
V	2	(13%)	0	(0%)	12	(80%)	11	(73%)

n=15

refers to the number of teachers at that level.
(%) refers to the percent of teachers at that level or higher.

Based on interviews in the spring of 1987 and 1988.

When implementation reaches a level of IVA or IVB, the likelihood that the innovation will result in lasting changes is greatly increased. With 80% of the teachers at level IVA or higher and 52% at level IVB or higher on strategies, and 54% at level IVA or higher and 41% at level IVB or higher on epistemology, the modification in instruction should be sustainable.

ACMI data after Stage Four indicated that teachers had continued their development during their second year in the program. The percentage of teachers at level IVB with respect to use of a constructivist epistemology had doubled. More than two thirds of the teachers reached level V, suggesting that they were beginning to take leadership roles in their district with respect to dissemination. In addition to co-leading ELM workshops, their ELM experiences propelled many of the teachers into accepting additional leadership roles and undertaking related challenges.

Impact on Students

Information on how the program affected students was collected in three modes: pre- and post-program attitude surveys, pre- and post-program standardized test scores, and teachers' reports of student change.

Attitude Surveys

Attitude surveys were given to parallel classes (grades four and above) of participating teachers at the end of the academic year prior to entering the program and again at the end of the following academic year, after Stages One and Two. The students answering the survey were not the same individuals from one year to the next, but were students taking the same course with the same teacher. Thus, surveys were included only for classes of teachers who taught the same course two years in a row.

Attitude scores for elementary students (grades four through six) were calculated from 171 pre-program surveys and 179 post-program surveys. Two-tailed t-tests were run to compare pre- and post- survey responses.

The general attitude score for elementary students showed a highly significant increase ($p<.001$). Looking at specific items that comprised the general score, the following items changed at a level of $p<.005$:

It is fun to work math problems.
I'd rather do math than any other kind of homework.
Math is one of my favorite classes in school.
It is interesting to do story problems.
Math helps me learn to think better.
I like to explain how I solved a problem.

In answer to the question, "To do well in mathematics, how important are these?" the following items increased in importance at a level of $p<.05$:

checking your own answers
being able to explain what you did
drawing diagrams
luck
being creative
trying new things to see how they work
seeing connections between things you've learned
trying different ways to solve problems even if you're not sure how to solve them
opinions

The following items decreased in importance at a level of $p<.05$:

working problems quickly
reading the textbook
writing down what the teacher says in class

Survey scores for the following items indicated no change from one year (pre-program) to the next (post-program):

neatness
asking questions in class
memorizing
thinking logically

In general, the responses are consistent with the goals of the program. The only surprising item is that "luck" increased in importance to doing well in mathematics. The actual mean, however, although it increased, still assessed luck to be unimportant.

For secondary students responding to the questionnaire, there were 295 pre-program surveys and 303 post-program surveys. The composite general attitude scores indicated no significant change from one year to the next. Significant differences were found for some of the items concerning what contributes to doing well in mathematics.

The following items increased at the level of $p<.05$:

being creative
trying new things to see how they work

The following items decreased at the level of $p<.05$:

reading the textbook
writing down what the teacher says
thinking logically

These responses are also consistent with the goals of the program, except "thinking logically." Here, too, although the mean decreased from one year to the next, it was still assessed to be important.

Standardized Tests

As with the attitude surveys, standardized tests were given to parallel classes of participating teachers at the end of the academic year prior to their entering the program and one year later, after completion of Stages One and Two. The number of students who took the test are as follows: 380 pre- and 388 post-program elementary students and 290 pre- and 303 post-program secondary students. Two-tailed t-tests were used to compare pre- and post-program test scores. No significant differences were found.

Teacher Observations

Observations of student behavior were solicited from sixty-one ELM teachers, the twenty-nine who participated in Stage Two in 1987-88 and the thirty-two Advanced level teachers. They were asked to describe effects their work in the ELM Project seemed to have on their students. Thirty-five teachers responded in writing. Both positive and negative effects were observed by the teachers. However, the positive effects were overwhelmingly the majority.

The only negative effect reported by more than one teacher (5) was that students experience more frustration.

Following is a list of the positive effects which were reported by at least five teachers. The number of teachers reporting the observation is in parentheses.

Students:

show greater ability to express mathematical ideas and to defend their point of view.(16)

express more interest and/or enjoyment in mathematics.(13)

listen to and respect others' ideas.(9)

show greater cooperation among themselves.(9)

willingly use concrete manipulatives to solve problems.(8)

take risks / share their strategies with the class.(8)

understand that there is more than one way to solve most problems.(8)

depend more on each other and less on the teacher.(8)

participate more in class.(8)

probe for understanding.(6)

are more confident, competent problem solvers.(6)

understand more.(6)

are more confident in math.(5)

Discussion of Impact on Students

Although teachers' observations of their students need more objective corroboration, some tentative conclusions can be considered. Teachers' observations of their students changes could be categorized in three broad areas: cognitive, affective, and social. These areas of perceived change, in addition to the attitude surveys and standardized test data, begin to describe ELM's impact on students.

1. Cognitive change: The cognitive changes that teachers described involved greater facility with mathematical ideas, greater ability to communicate about mathematics, and deeper understanding of mathematical concepts. The students became more competent problem solvers who understood that there is more than one way to solve most problems.

Even though classroom teachers increased their attention to ideas and concepts and decreased their emphasis on computational skills, there was no accompanying drop in standardized test scores. There is often a concern that greater attention to understanding and problem solving, particualrly considering the additional time needed initially for students to construct concepts, would result in a decrease in computational skill. There is also the concern that any changes in teaching of this magnitude would result in lower test scores for the first year or two as teachers learn the ropes. However, the standardized post-tests administered after only one year of classroom implementation showed no change from the pre-tests.

2. Affective change: Teachers reported that their students now expressed more interest and enjoyment in mathematics, and that they demonstrated more confidence in problem solving and in mathematics in general.

The attitude survey scores supported the teachers' observations. After the teachers' participation in ELM, elementary students more frequently reported that it is fun to work mathematics problems, that they liked to explain how to solve problems, and mathematics helps them to think better.

The changes in attitude, as evidenced from the survey, were more dramatic among elementary students than secondary students. The composite attitude score significantly increased ($p<.001$) for the elementary students, while secondary students significantly changed on only a few items. Older students' attitudes toward mathematics may have been more firmly set by more years in school. For the older students, one year of modified instruction was probably not sufficient for considerable impact on attitudes that had been developed over many years. Two or more years of involvement in constructivist-based mathematics classes might have far greater impact. It is also possible that the fact that elementary teachers are with their students for much of the day may have helped elementary students to make a change in their learning more rapidly and ultimately make a greater change in attitudes.

An unexpected result from the attitude survey was the increase in elementary students' perception of the importance of luck. Perhaps the change reflects students different perceptions of computational exercises versus non-routine problems. If pre-ELM problems were largely computational exercises, then luck played little or no role. Success was dependent on careful repetition of a known algorithm. During ELM, teachers gave non-routinge problems for which trying different strategies was appropriate, and students might have identified stumbling onto a successful strategy as luck. It must be noted, however, that although there was significant change, luck was still viewed as relatively unimportant.

Similarly, the decrease in the perceived importance of logical thinking among secondary students is puzzling. It may be that logical thinking was stressed more overtly by teachers pre-ELM. Again, although there was a significant change, logical thinking was still viewed as important.

3. Social change: Among teacher-reported changes, it is interesting to note how many of the observations reflected changes in social behavior. Teachers wrote that students showed greater cooperation among themselves and that they listened to and respected each other's ideas. Students were more willing to take risks and to share their ideas and strategies with their classmates. Students were more willing to participate in class.

Although all of these points are particularly stressed and practiced in ELM, they could be considered to be values of the traditional classroom as well. One item, however, characterizes a change that is particular to instruction based on constructivism: that students now depend more on each other and less on the teacher. This probably reflects a change in the locus of authority (how mathematical validity is encouraged) and the encouragement of independent thinking which tend to be associated with constructivism.

Impact on Districts

Impact on districts was assessed by means of district (non-ELM) teachers' evaluations of Stage Four workshops and questionnaire responses from district administrators.

Stage Four Workshops

Stage Four of the ELM Project was designed to disseminate new ideas and teaching methods beyond individual teachers' classrooms to the entire school or district. Advanced Level ELM teams, which included ELM staff and Advanced Level teachers, planned and conducted workshops for colleagues in their districts. During the 1986-87 academic year, seven teachers working in pairs or groups of three conducted a total of 10 workshops, and during the 1987-88 academic year, fourteen teachers conducted a total of 23 workshops. In a few districts scheduling difficulties resulted in the number of workshops conducted being fewer than the number originally projected.

The workshops emphasized working on non-routine mathematics problems, using diagrams and manipulatives, verbalizing ideas, and working in groups. In each workshop, participants worked on mathematics problems in order to experience, from the perspective of the student, a classroom which fosters the active construction of mathematical ideas. The participants were then asked to consider the implications of their own learning experiences in the workshop as they apply to teaching in their mathematics classes.

Although we do not have participants' evaluations of all of the workshops, the following summarizes the 82 responses that were received:

My participation in the workshop was:

very useful	useful	slightly useful	not useful
25%	57%	18%	0

The instructors' knowledge of the subject matter was:

excellent	good	poor
80%	20%	0

The instructors' responsiveness to participants was:

excellent	good	poor
79%	21%	0

Open-ended responses from the participants indicated that they liked "the idea of constructing visual and manipulative aids in order to analyze a problem," "the challenge of the problems," "bringing an abstract idea into a concrete one," "group thinking," "being encouraged to voice my opinion," and "the idea of exploring and discovering things for myself."

However, not everybody was convinced. Some participants said that they disliked "the fact that the majority of students I teach will not comprehend what I want of them if I teach this way," "the lack of a structured situation," and the fact that "I'm doing the work as opposed to the instructor."

The ELM teachers who led the workshops reported that they were aware of several teachers in their schools who tried out ideas presented in the workshops. Some teachers started to emphasize using diagrams in the solutions of word problems and understanding concepts; some teachers experimented with pair and group work in their classrooms; and some teachers asked for recommendations of curriculum sources. Compared to the changes in ELM teachers classrooms, however, these initial attempts were much less widespread and very tentative.

Administrators' Feedback

In April 1988, 45 administrators were sent questionnaires. Twenty-five administrators completed and returned them. (20 initial level questionnaires and 12 advanced level questionnaires were returned.)

Mean responses to the short items were as follows: (items were rated from 1 to 4)

Initial Level:

Overall evaluation of the follow-up program: 3.8

Benefits for your teachers: 3.7

Did you feel welcome to attend the workshops? 3.8

Did you feel encouraged to learn more about the program? 3.6

How knowledgeable have you become about the program? 2.8

Advanced Level:

Overall evaluation of the Advanced Level of the program: 3.8

Benefits for your ELM teachers: 3.9

Benefits for your other teachers: 3.1

Did you feel encouraged to learn more about the program? 3.4

How knowledgeable have you become about the program? 3.0

Likelihood of the ELM initiative to be sustained in your district: 3.4

Open-ended responses to these questionnaires provided insight into administrators' perceptions of the impact of the program on their teachers and also gave information particularly focused on district-wide goals.

Most administrators remarked on the excitement and growth that they saw in the ELM teachers:

> For me, the greatest value of the Initial Level lies in the fact that it convinced our mathematics department head [who was a participant] ... to see that change was not only possible, but desireable.

> The several teachers from various elementary schools and the high school have become true believers in their students capacity to learn math.

> Veteran teachers have become energized by ELM and especially sensitized to pupils having difficulty.

One administrator, however, was concerned about a teacher's interpretation of the program:

> I believe that some teachers have had problems with the theory to practice organization of the summer program. I have had some experience where a teacher seemed to misread the constructivist theory to where there were no outcomes or skills learned, only process gone through.

Several administrators reported on the changes that they saw when they visited ELM teachers' classrooms.

> Emphasis seen in hands-on approaches in class and pupil verbalizing their understandings.

> Teachers who are enthusiastic about the project report not only better results in terms of student achievement, but also a different tone in the classroom.

> I came to the district after two of the teachers had completed the Advanced Level of ELM, so I know relatively little about the projects, but I have been able to see the benficial results in the classroom mathematics instruction of those who participated. The spirit of inquiry and interest in math which they create with their students is extraordinary. They consistently challenge students to think, to problem-solve, to find alternative strategies, to examine the process of their mathematical thinking.

> I can recommend the Project highly from the results I have seen.

One department chair, however, was concerned about the time demands of these new approaches.

> A number of students seem to have gained both confidence and understanding. In terms of time the price has been high. Any new venture will have bugs to be worked through. I anticipate that next year the time factor will be more on line.

Administrators also addressed the impact of the program beyond ELM teachers' classrooms.

> Our math curriculum is under revision and ELM Project involvement has meant that we are building our program from the viewpoint of pupil learning rather than standardized test measures or textbook curriculum.

> The teachers have offered workshops for teachers and parents which were very successful.

> Other teachers are beginning to use some of the strategies that were show cased in the workshops. In short, minds have been opened. Who could ask for anything better thant that?

> I think that the impact of this program may be ever more significant than we realize now.

Discussion of Impact on Districts

The impact of the ELM Project has been generally reported by school district administrators as important and positive. Their written feedback was strongly supportive and they found funds to expand participation of teachers at the Advanced Level. There seems to have been a consensus that the program benefited the ELM teachers and that the direction is a beneficial one for their districts.

Whereas the workshops led some teachers to try new strategies, overall impact on district teachers were very modest. Teachers who did not participate in ELM did not receive either the extensive learning opportunity nor the on-going classroom support that facilitated the significant changes in the ELM teachers.

CHAPTER 5

CONCLUSIONS

The Initial and Advanced Levels of the ELM Project were each designed with a specific goal in mind. The Initial Level was designed to introduce constructivism and related instructional methods to teachers and to support those teachers as they modified their classroom instruction. The Advanced level was focused on dissemination of new approaches throughout paricipating school districts. ELM was very successful with the former. However, with the latter, only tentative first steps were made.

ELM demonstrated the significant impact of combining summer inservice institutes based on constructivism with intensive, ongoing follow-up support. Teachers not only integrated new strategies into their instruction, but also began the difficult task of developing an explicit, individual view of mathematics learning as a basis for their instructional decisions. Along with the learning came added respect for the enormity of what there is to learn, optimism about their potential impact on students, and commitment to continued development.

The successes of the Initial Level of the ELM Project should be interpreted in light of the fact that teachers voluntarily became involved in the program. Although the majority of them initially understood little more than that ELM was a chance to learn some new ideas for mathematics instruction, this population was select. Participating teachers were interested in improving as teachers of mathematics, were willing to devote two weeks of their summer to such improvement, and were willing to work with an ELM staff member on a weekly basis. ELM does not offer information about how results would be different if participation were mandated. What is more, difficult questions arise over the possible contradiction between the empowerment that ELM teachers experienced in the program and the notion of mandatory participation.

The model provided by ELM, while successful in engendering change in the participants, is one which is labor and cost intensive. Replication of such a model would require a serious commitment of resources. The cost will have to be weighed against the potential long range benefits including improved instruction, teacher leadership, teacher renewal and retention, and impact on other areas of the curriculum, particularly at the elementary level.

The ELM approach to mathematics instruction fits well with the recently developed National Council of Teachers of

Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics (1987). The constructivist view is clearly stated in the Standards:

> In most classrooms, the conception of learning is that students are passive absorbers of information, storing it in easily retrievable fragments as a result of repeated practice and reinforcement. Research findings from psychology indicate that learning does not occur by passive absorbtion (Resnick, 1986). Instead, individuals approach each new task with prior knowledge, assimilate new information, and construct their own meanings. (Draft p.8)

The Standards go on to emphasize the key role of "problem situations" in the development of mathematical knowledge. They point out the importance of exploration, multiple representations, understanding of mathematical operations, justification of arguments, applications, and the communication of mathematical ideas.

The changes documented by the ELM attitude surveys and those observed by ELM teachers are consistent with the Standards' "Goals for Students." These goals are:

(1) becoming a mathematical problem solver,
(2) learning to communicate mathematically,
(3) learning to reason mathematically
(4) learning to value mathematics, and
(5) becoming confident in one's ability to do mathematics.

The ELM approach to mathematics instruction is also significant in its potential for female and minority students. These instructional methods are consistent with the results of a study conducted by the Office of Opportunities in Science (American Association for the Advancement of Science, 1984). This report identifies characteristics of programs that produce successful mathematics and science education for underrepresented populations. At the classroom level, their research "supports the notion of peer-grouped curriculum with a good deal of hands-on work and a constant interplay between theoretical and practical activity." (Cole and Griffin, 1987).

Much of the success of ELM can be attributed to the opportunities it provided for teachers which did not exist previously. These included:

1. the opportunity for teachers to develop their own epistemologies as the basis for curriculum and instructional

decisions. Whereas previously teachers may have looked to be told what to teach and how to teach it, when they develop their own epistemology they become able to base decisions on their own informed, professional judgement. These decisions are increasingly made in response to the particular needs and levels of understanding of the students.

2. the opportunity to communicate with other teachers. It is an often-discussed phenomenon that teachers tend to be professionally isolated in their own classrooms. ELM has provided teachers regular opportunites for professional dialogue, has generated focus for such dialogue, and has established a support group for working on improved instruction in mathematics.

3. the opportunities for teachers to emerge as educational leaders. The Advanced Level of ELM allowed teachers to build on their classroom successes. Teachers identified that which they have to offer other educators and worked on developing the skills to do so successfully. This was a small, but useful, step in moving teachers towards their appropriate role as the experts on learning and teaching in their districts and communities.

The ELM results are also significant in the relationship demonstrated between the changes made and students' standardized test results. Whether the standardized tests are seen as effective measures or not, many districts still put considerable emphasis on the test results. ELM demonstrated that teachers can make student understanding and problem solving high priority without sacrificing test results. What is more, ELM demonstrated that test results could be kept stable even during the first year that teachers are making such changes. These results will perhaps make it possible for more school districts to become involved with such teacher development efforts without concern for giving up what they have accomplished in developing computational skills and high test scores.

Another important step taken by ELM was the further work on identifying the particular assessment issues to which a constructivist program gives rise. The development of the ACMI instrument provides a way of assessing whether teachers are implementing instruction based on constructivism.

Limitations of ELM

Although the ELM Project has been very successful, not all of the goals have been fully met. Specifically, we see three areas that have yet to be addressed: 1) whereas ELM teachers have implemented significant innovations in their own classrooms, we see little change throughout the districts in their colleagues' classrooms; 2) as ELM teachers develop teaching approaches based on a constructivist view of learning, they run up against the limits of their own backgrounds in mathematics (more common for elementary teachers); and 3) ELM teachers have not been provided with enough modeling of instruction or curriculum development. These limitations are discussed more fully below.

1) Limited Change in the Districts

Teachers who have participated in the ELM Project have demonstrated remarkable changes in their own classrooms. On the whole, however, we did not see significant changes throughout the districts beyond these classrooms. The Advanced-Level workshops that ELM teachers conducted in their districts have provided a forum for the presentation and discussion of ideas and methods introduced in the Summer Institutes and have stimulated many teachers to seek opportunities for further learning. Yet, a series of two to four afternoon sessions is not sufficient to effect change in the classroom.

Only a few ELM teachers have had the opportunity to work extensively with colleagues. Sacrificing their own planning periods, they talked with them about constructing understanding and went into colleagues' classes to demonstrate methods.

2) Limits of Teachers' Mathematical Background

Many ELM teachers, particularly those from elementary and middle schools, have not been trained specifically in mathematics. Following their ELM experiences, a number of these teachers requested a course whose focus is mathematics content (not the typical request of elementary teachers). They said that their experience in the Summer Institutes provided a new perspective on their own previous avoidance of and weakness in mathematics. Through the lessons taught by project staff, many elementary teachers, for the first time, began to see themselves as able to learn mathematics. They felt the excitement of discovering their own solutions to mathematics problems and connecting concepts that previously had seemed isolated pieces of information. With the help of project staff during the follow-up program, they were often able to transmit the same excitement to their students.

However, the development of lessons which foster powerful constructions requires considerable understanding of the concepts to be taught and the interrelationships between these concepts. Lessons are developed so that classroom activities and experiences already familiar to students form the foundations for the new concepts. Concepts are approached using a variety of contexts and representations, rather than taught as isolated skills.

Furthermore, teachers must be able to examine students' error patterns to discover misconceptions and gaps of understanding. They must find where students' mathematical foundations are firm in order to develop lessons that will ground the concepts in concrete experience. Since this work is done interactively between teacher and student, a teacher must understand concepts well enough to generate questions that help the students extend their understanding.

It is the thorough understanding of the structure of the mathematics that was missing for many of the ELM teachers.

3) Limited Exposure to Constructivist Instruction.

The constructivist teacher needs not only a deep understanding of mathematical concepts, but also a breadth of curriculum ideas for presenting concepts from a variety of perspectives grounded in students' experience. Different from the traditional teacher, the constructivist must also be skilled in drawing out students' thoughts about mathematical concepts and problems in order to explore their understandings and misconceptions. The modeling provided during the Summer Institutes and the demonstration lessons conducted by project staff during follow-up were crucial to teachers' development in a constructivist direction. However, the teachers, both elementary and secondary, are requesting more modeling.

The ELM instruction often modeled only single lessons rather than larger units. One ELM teacher, trying to articulate his needs, referred to the model lessons as "golden nuggets." The modeling does not allow teachers to follow the development of a concept over several days or weeks, or observe the follow-through once initial concepts are discovered. Teachers are asking for opportunities to observe whole series of lessons.

Assessment Limitations: In addition to these three areas concerning teacher development, limitations also existed in the methods used to evaluate the Project. Objective tools were not available to measure many of the changes that teachers observed in their students (eg. increased problem solving abilities, greater abilities to articulate mathematical ideas, greater understanding of mathematical concepts). In addition, the reliability of the ACMI data would have been increased by an independent, formal observational tool for assessing teachers' instructional approaches.

Next Steps

In response to the perceived limitations in teacher development, the Mathematics Leadership Network (MLN) was established to build upon the successes of ELM and extend its work. MLN, which began in September 1988, introduces two major new components to the project: a resource teacher internship program and coursework offered during the academic year.

1. Resource Teacher Internship Program: Through the resource teacher internship program, MLN intends to build district self-sufficiency in disseminating the teaching approaches generated in ELM. As in ELM, a central component is classroom follow-up. In MLN, however, participating teachers will themselves be trained as resource teachers and they will conduct follow-up for their colleagues. This will provide districts with the leadership necessary to continue the project after MLN expires.

2. Two new academic-year courses: In addition to the three two-week Summer Institutes, MLN will offer two new semester-long courses.

The course for elementary teachers will focus on the mathematics content. This intensive course will provide teachers with a unique opportunity to explore mathematics concepts in depth and discover how these concepts are related to one another. In addition, the elementary course will itself be a model of instruction. Thus, teachers will be exposed to curricular approaches that ground mathematics concepts in students' experience. (They will observe how one can develop a concept over several lessons and continually build on content already addressed in the course.) They will also receive consistent modeling of the teacher's role in a classroom based on constructivism.

The need for a course for secondary teachers is related primarily to the abstract and complex nature of many of the concepts to be taught. Since these concepts are often more removed from everyday experience, many ELM teachers have said that they find it difficult to root the concepts in what students already understand. Thus, the course for secondary teachers will not only focus on isolating the major concepts and subconcepts on which curriculum topics are built, but will also explore the connections between these concepts and physical models.

The MLN courses will first be offered in the spring semester, 1989, and the resource teacher internship program will begin in September, 1989.

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APPENDIX A

Questionnaires

SUMMERMATH FOR TEACHERS 1988

Elementary Institute

Course Evaluation

Please evaluate the following:

(5 = excellent; 4 = very good; 3 = good; 2 = fair; 1 = poor).

Choose one whole number for each item.

After you choose each rating, specify the factors which most influenced this evaluation.

___ My overall evaluation of the Institute. Describe three experiences which most influenced this evaluation.

___ Mathematics Lessons (Problems in more than one way, Boxes, Xmania) Comments:

Please evaluate the following:

(5 = Strongly Agree; 4 = Agree; 3 = No Opinion;

2 = Disagree; 1 = Strongly Disagree).

Choose <u>one</u> <u>whole</u> number for each item.

___ I expect that the Institute will have an impact on my teaching practices.

___ My enthusiasm for teaching is high as I leave the Institute.

___ The Institute has made me aware of new teaching strategies which I plan to use in my classroom.

___ The Institute has challenged me mathematically.

___ The Institute has made an impact on my perspectives on teaching and learning

___ Interview and tutorial with students. Comments:

___ Activities on implementation. Comments:

___ Tennis/Dance component. Comments:

___ Logo class -- computer time. Comments:

___ Logo class -- group discussions. Comments:

___ Cultural sharing. Comments:

___ Evening activities on Women and Mathematics by Joan Ferrini-Mundy. Comments:

___ Dinner with past SummerMath for Teachers participants. Comments:

In what ways can the learning experience of the Elementary Institute be improved?

We as a staff care about improving our teaching. If you have feedback for individuals or the staff as a team, please write your comments in the space below. Please include both things of importance that you valued and also significant improvements that would have changed your institute experience. (Please remember that criticism is heard better when stated in a supportive manner).

Comments on programme ecology (food, physical facilities, class schedule etc.):

Please add any additional thoughts you would like to share with us:

Thank you.

SUMMERMATH FOR TEACHERS 1988

Secondary Institute

Course Evaluation

Please evaluate the following:

(5 = excellent; 4 = very good; 3 = good; 2 = fair; 1 = poor).

Choose one whole number for each item.

After you choose each rating, specify factors that affected this evaluation.

___ My overall evaluation of the Institute. Describe three experiences which most influenced this evaluation.

___ Mathematics Lessons led by SummerMath for Teachers staff (Fractions and Averages). Explain:

___ Opportunity to develop lessons and get feedback (Monday and Wednesday, second week). Explain:

___ Interview and tutorial with SummerMath students.
Explain:

___ Tennis/Dance component. Explain:

___ Logo class. Explain:

___ Geometric Supposer class. Explain:

___ Exploration of other computer software. Explain:

___ Evening sessions (Piaget and Equity). Explain:

Please evaluate the following:

(5 = Strongly Agree; 4 = Agree; 3 = No Opinion;

2 = Disagree; 1 = Strongly Disagree).

Choose <u>one</u> <u>whole</u> number for each item.

____ The Institute will have an impact on my teaching practices. Explain:

____ My enthusiasm for teaching is high as I leave the Institute. Explain:

____ The Institute has challenged me mathematically.

____ The Institute has challenged me as an educator.

____ The Institute has made an impact on my perspectives on teaching and learning.

In what ways can the learning experience of the Secondary Institute be improved?

We as a staff care about improving our teaching. If you have feedback for individuals or the staff as a team, please write your comments in the space below. Please include both what you valu·d and what you think could be improved.

Comments on program ecology (food, physical facilities, class schedule, etc.):

Please add any additional thoughts you would like to share with us:

Thank You

SUMMERMATH FOR TEACHERS 1988

Advanced Institute

<u>Course Evaluation</u>

Please evaluate the following:

(5 = excellent; 4 = very good; 3 = good; 2 = fair; 1 = poor).

Choose <u>one</u> <u>whole</u> number for each item.

___ My overall evaluation of the Institute. Describe three experiences which most influenced this evaluation.

___ Mathematics Lessons led by SummerMath for Teachers staff (area, perimeter, polygons, combinatorics, fractions). Comments:

___ First, Second, and Third learning experiences.
Comments:

___ Shared experiences (tutorial). What did you learn?

___ Preparation for leading inservice workshops. Comments:

Please evaluate the following:

(5 = strongly agree; 4 = agree; 3 = ambivalent or no opinion; 2 = disagree; 1 = strongly disagree)

___ The Advanced Institute will have an impact on my teaching practices. Explain:

___ My enthusiasm for teaching is high as I leave the Institute. Explain:

___ The Advanced Institute has challenged me mathematically.

___ The Advanced Institute has challenged me as an educator.

___ The Advanced Institute has had an impact on my perspectives on teaching and learning.

In what ways can the learning experience of the Advanced Institute be improved?

We as a staff care about improving our teaching. If you have feedback for individuals or the staff as a team, please write your comments in the space below. Please include both what you valued and what you think could be improved.

Comments on program ecology (food, physical facilities, class schedule, et

Please add any additional thoughts you would like to share with us:

Thank You.

EVALUATION OF THE

ELM PROJECT FOLLOW-UP PROGRAM*

(*Follow-up program refers to the weekly classroom work with the consultant).

Directions: This questionnaire is to collect feedback on the feelings of teachers about their participation in the Follow-up Program.

All responses are to be anonymous, so please do not put your name on the questionnaire.

Part One:

1. What effects has your participation in SummerMath for Teachers had on your teaching and your students' learning?

2. What difficulties have you experienced in trying to implement what you learned in the program?

3. The thing I liked best about the Follow-up Program was:

4. The thing I liked least about the Follow-up Program was:

Part Two:

Please respond to every item. No item should have more than one response.

Each item below is a statement followed by abbreviations of the following responses: Strongly Agree (SA), Agree (A), Neutral or Undecided (N), Disagree (D) and Strongly Disagree (SD). Circle one and only one response for each item.

Please feel free to write in an explanation of any answer.

1. The Follow-up Program has helped me become a more effective teacher.

   SA A N D SD

2. The Follow-up Program has taken time that could have been better spent on other tasks.

   SA A N D SD

3. I looked forward to my weekly visitation.

   SA A N D SD

4. The Follow-up Program has caused me anxiety.

   SA A N D SD

5. The Follow-up Program has lessened my enjoyment in teaching mathematics.

   SA A N D SD

6. I was free to choose which aspects of teaching that I work on in the Follow-up Program.

   SA A N D SD

7. The balance of positive feedback and criticism that I received was good.

   SA A N D SD

8. It is difficult for me to speak openly with the Follow-up Program consultant working with me. (Consultant = Ellen, Deborah, Cathy, Virginia, or Marty).

   SA A N D SD

9. The Follow-up Program is having a positive effect in subject areas other than math. (Put N/A if you teach only math).

SA A N D SD

10. The Follow-up Program has decreased my confidence as a math teacher.

SA A N D SD

11. Demonstration teaching by my Follow-up Program consultant has been helpful to me.

SA A N D SD

12. My consultant lacks the experience that he/she should have.

SA A N D SD

13. The Follow-up Program has allowed me to clarify what I learned in SummerMath for Teachers.

SA A N D SD

14. The visitations are disruptive to my classroom teaching.

SA A N D SD

15. What I am working on with my consultant is relevant to my goals in teaching mathematics.

SA A N D SD

16. The amount of time per week should be ...

a) increased b) decreased c) kept as is

<u>Additional Comments</u>: (please use the back)

THANK YOU

FEEDBACK

for Stage Four of the ELM Project

How many workshops did you co-lead?

How many more are planned for the current school year?

Please outline the goals and activities for each:

Workshop 1:

District ________________

Grades ________________ Date ________________

Workshop 2:

District ________________

Grades ________________ Date ________________

Workshop 3:

District ________________

Grades ________________ Date ________________

Workshop ___

District ________________

Grades ________________ Date ________________

How frequently did you meet with ELM staff and other ELM participants to plan workshops?

What was good about the planning meetings?

How can workshop preparation be improved?

How did you feel about your role conducting the workshop?

How did the participants respond?

Have you heard of any classroom changes as a result of the workshops? __________ If yes, what were they?

Has working in Stage Four (leading workshops) made you a better math teacher? __________ If yes, how?

Has working in Stage Four made you a better workshop presenter? ____________ If yes, how?

Do you have any other comments about Stage Four of the ELM Project?

SUMMERMATH FOR TEACHERS

ADMINISTRATOR EVALUATION

Initial Level 1988-1989

Name: ______________________________ Position ______________.

School District: __________________________________

1. Please describe your evaluation of the Initial Level of the SummerMath for Teachers Program which consisted of your teacher(s)' participation in summer institutes, weekly classroom visitations and consultations, plus four academic year workshops. Please discuss the strengths and weaknesses of the program and any particular value that the program had for your teacher(s).

Please return to: Deborah Schifter
SummerMath for Teachers
Mount Holyoke College
South Hadley, MA 01075

2. List any suggestions that you have for the future.

Please rate the following:

3. Overall evaluation of the follow-up program:

Poor			Excellent
1	2	3	4

4. Benefits for your teachers:

None			Substantial
1	2	3	4

5. Did you feel welcome to attend the workshops?

Definitely Not			Definitely
1	2	3	4

6. Did you feel encouraged to learn more about the program?

Definitely Not			Definitely
1	2	3	4

7. How knowledgeable have you become about the program?

Not at all			Quite
1	2	3	4

COMMENTS:

SUMMERMATH FOR TEACHERS

ADMINISTRATOR EVALUATION

Advanced Level 1988-1989

Name: ______________________ Position ____________________

School District: ______________________________

Please describe your evaluation of the Advanced Level of the SummerMath for Teachers Program which consisted of your teachers' participation in the two-week Advanced Institute plus their conducting academic year inservice workshops for colleagues in your district. Discuss the strengths and weaknesses of the program, any particular value that the program had for your teachers, and any involvement of SummerMath teachers in district projects which was a bi-product of their program experience.

Please return to:

Dr. Deborah Schifter
SummerMath for Teachers
Mount Holyoke College
South Hadley, MA 01075

2. List any suggestions that you have for the future:

Please rate the following:

3. Overall evaluation of the Advanced Level of the program:

Poor			Excellent
1	2	3	4

4. Benefits for your SummerMath teachers:

None			Substantial
1	2	3	4

5. Benefits for your other teachers:

None			Substantial
1	2	3	4

6. Did you feel encouraged to learn more about the program?

Definitely Not			Definitely
1	2	3	4

7. How knowledgeable have you become about the program?

Not at all			Quite
1	2	3	4

8. Likelihood that the SummerMath initiative will be sustained in your district:

None			Great
1	2	3	4

COMMENTS:

APPENDIX B

Student Attitude Surveys

DO NOT PUT YOUR NAME ON THIS

STUDENT SURVEY

We are interested in your ideas about mathematics. Your answers to the questions that follow will help us to understand how you feel about mathematics.

This questionnaire is not part of your regular school work, and you will not be graded. Your answers are completely anonymous. Please tell us what you REALLY think.

Thanks for your help!

0	1	2	3	4
Strongly Disagree				Strongly Agree

Put a number from 0 - 4 by each statement to express your feelings and thoughts.

____ 1. I enjoy going beyond the assigned work and trying to solve new problems in mathematics.

____ 2. Mathematics is enjoyable and stimulating to me.

____ 3. Mathematics makes me feel uneasy and confused.

____ 4. I am interested and willing to use mathematics outside school and on the job.

____ 5. I have never liked mathematics, and it is my most dreaded subject.

____ 6. I have always enjoyed studying mathematics in school.

____ 7. I would like to develop my mathematical skills and study this subject more.

____ 8. Mathematics makes me feel uncomfortable and nervous.

____ 9. I am interested and willing to acquire further knowledge of mathematics.

____ 10. Mathematics is dull and boring because it leaves no room for personal opinion.

____ 11. Mathematics is very interesting, and I have usually enjoyed courses in this subject.

____ 12. Mathematics has contributed greatly to science and other fields of knowledge.

____ 13. Mathematics is less important to people than art or literature.

____ 14. Mathematics is not important for the advance of civilization and society.

____ 15. Mathematics is a very worthwhile and necessary subject.

____ 16. An understanding of mathematics is needed by artists and writers as well as scientists.

____ 17. Mathematics helps develop a person's mind and teaches him to think.

____ 18. Mathematics is not important in everyday life.

____ 19. Mathematics is needed in designing practically everything.

____ 20. Mathematics is needed in order to keep the world running.

____ 21. There is nothing creative about mathematics; it's just memorizing formulas and things.

Student Survey

0 - Not important at all
1 - Of little importance
2 - Moderately important
3 - Important
4 - Extremely important

Put a number (0 - 4) by each of the following.

To be successful in mathematics, which of the following are most important?

____ 1. Working problems quickly
____ 2. Checking answers to problems
____ 3. Being able to explain what you did
____ 4. Neatness
____ 5. Asking questions in class
____ 6. Drawing diagrams
____ 7. Reading the textbook
____ 8. Memorizing formulas, etc.
____ 9. Luck
____ 10. Writing down what the teacher says in class
____ 11. Thinking logically
____ 12. Being creative
____ 13. Trying new things to see how they work
____ 14. Seeing how different things you have learned are connected
____ 15. Trying to do problems if you don't know how to solve it immediately

---

lease answer the following:

How long do you spend on a homework problem before you give up?

What change on your part would make you a better math student?

DO NOT PUT YOUR NAME ON THIS

STUDENT SURVEY

We are interested in your ideas about mathematics. Your answers to the questions that follow will help us to understand how you feel about mathematics.

This questionnaire is not part of your regular school work, and you will not be graded. Your answers are completely anonymous. Please tell us what you REALLY think.

Thanks for your help!

ATTITUDES TOWARD MATH

Birth Date:
Teacher's Name:
Grade:
Current Year:

Agree	Don't Know	Dis-agree		
[ ]	[ ]	[ ]	1.	It is fun to work math problems.
[ ]	[ ]	[ ]	2.	It is important to take math every year until you are out of school.
[ ]	[ ]	[ ]	3.	If I could skip just one class, it would be math.
[ ]	[ ]	[ ]	4.	Most of my friends are better at math than I am.
[ ]	[ ]	[ ]	5.	Most people who work need to know something about math for their jobs.
[ ]	[ ]	[ ]	6.	Math is boring.
[ ]	[ ]	[ ]	7.	I'd rather do math than any other kind of homework.
[ ]	[ ]	[ ]	8.	Math is one of my favorite classes in school.
[ ]	[ ]	[ ]	9.	Someone who likes math is usually weird.
[ ]	[ ]	[ ]	10.	I like to do math number problems.
[ ]	[ ]	[ ]	11.	People who have a calculator or a computer need very little math.
[ ]	[ ]	[ ]	12.	We learn about math in school, but rarely use it outside of school.

Agree	Don't Know	Dis-agree		
[ ]	[ ]	[ ]	13.	We study too much math in our school.
[ ]	[ ]	[ ]	14.	I already know as much as I need to know about math.
[ ]	[ ]	[ ]	15.	I have always liked math.
[ ]	[ ]	[ ]	16.	It is interesting to do story problems.
[ ]	[ ]	[ ]	17.	I enjoy doing math puzzles in my spare time.
[ ]	[ ]	[ ]	18.	Doing mathematics makes me nervous.
[ ]	[ ]	[ ]	19.	Math helps me learn to think better.
[ ]	[ ]	[ ]	20.	I like to explain how I solved a problem.

To do well in mathematics, how important are these?

Very Important	Useful	Not Important		
[ ]	[ ]	[ ]	1.	Working problems quickly
[ ]	[ ]	[ ]	2.	Checking your own answers
[ ]	[ ]	[ ]	3.	Being able to explain what you did
[ ]	[ ]	[ ]	4.	Neatness
[ ]	[ ]	[ ]	5	Asking questions in class
[ ]	[ ]	[ ]	6.	Drawing diagrams
[ ]	[ ]	[ ]	7.	Reading the textbook
[ ]	[ ]	[ ]	8.	Memorizing
[ ]	[ ]	[ ]	9.	Luck
[ ]	[ ]	[ ]	10.	Writing down what the teacher says in class
[ ]	[ ]	[ ]	11.	Thinking logically
[ ]	[ ]	[ ]	12.	Being creative
[ ]	[ ]	[ ]	13.	Trying new things to see how they work
[ ]	[ ]	[ ]	14.	Seeing connections between things you have learned
[ ]	[ ]	[ ]	15.	Trying different ways to solve problems even if you are not sure how to solve them
[ ]	[ ]	[ ]	16.	Opinions

Please answer the following:

How long do you spend on a homework problem before you give up?

What would make you a better math student?